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Summer Planting of White Spruce and Lodgepole Pine Seedlings

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INTRODUCTION

Reforestation of burned and cut-over areas in sub-boreal and boreal forests of North America has been hampered by a number of factors, including a generally short planting season and a restricted labour supply. These problems have stimulated research across Canada and the United States aimed at developing methods to permit the successful planting and establishment of seedlings during the entire period when areas scheduled for regeneration were free of snow or frozen soils. This report presents a brief review of the North American literature and discusses the results of recent attempts to extend the planting period in British Columbia throughout the snow-free season.

LITERATURE REVIEW

Reports published in the past 50 years discuss a range of factors which may influence seedling survival and growth after planting. Among these are season of planting, stock type, storage period, site preparation, soils, and vegetative competition.

Season

Lebarron *et al.* (1938) and Sutton (1982) review a number of papers which indicate that spring is the generally preferred planting season for a range of coniferous species in North America. Advantages commonly noted for spring planting are generally moist soils, cool, damp weather, and seedling physiology favourable for early resumption of shoot and root growth after planting. In much of North America, however, where plantations are subject to snow (and certainly over most of the interior of British Columbia), forest nurseries are generally located in areas that warm up more rapidly in spring than do locations of potential plantations. The result is a relatively brief period of time during which plantations may be established in spring with freshly lifted bareroot stock, or with container seedlings overwintered out-of-doors and in a stress-resistant dormant state. An alternative approach, frequently employed in British Columbia, is to use seedlings that have been kept over winter in cold storage facilities.

A further disadvantage of spring planting of fresh-lifted seedlings is that this period is not homogeneous and, as the temperature rises, both the environment and the physiology of planting stock become progressively less favourable for post-planting survival and growth (Mullin and Parker 1976; Mullin and Forcier 1979; Mullin and Reffle 1980). Sutton (1984:329) recommends the following:

> With pines, lifting and planting of fresh stock should be completed as early in the planting season as possible. With spruces, lifting and planting of fresh stock should be avoided during the period of most active shoot elongation. With all species, stress should be minimized, e.g. by good handling, good prompt planting and planting only in those soils that are moist, aerated, and warm enough to support vigorous growth of root.

The second most popular planting season is autumn (Sutton 1982). However, soils in late summer and early fall are often dry; weather patterns include warm days with high evapotranspiration stress; and the resistance to stress of coniferous seedlings may be low at this time (Stone *et al.* 1962; Hermann 1967; Lavender and Wareing 1972; Sinclair and Boyd 1973; Sutton 1982; Ritchie 1985). Recent studies at the University of British Columbia (UBC) suggest strongly that survival of fall-planted seedlings in British Columbia may be improved if the stock is subjected to short photoperiods in late summer (Silim *et al.* 1989).

Another criticism of fall planting is that seedlings may be more prone to frost heaving if planted at this time, as root elongation before winter is not sufficient to anchor them firmly (Crossley 1956; Limstrom 1963; Stiell 1976).

The obvious alternative to either spring or fall planting is to extend the spring planting season into the summer. Sutton (1982) reviews data from trials with a wide range of species implemented over a broad range of climates from the interior of British Columbia to Ontario. The reports demonstrate that "extended season or summer planting" may be very successful, but the data again are variable and reflect strong differences in seedling physiology at time of planting, and significantly different weather patterns during the planting season. Active seedling growth during the planting period frequently resulted in reduced shoot elongation (Mullin and Parker 1974; McClain 1982), while both drought (Ferdinand *et al.* 1974) and growing season frosts have been reported to cause seedling damage or mortality (A. Vyse, pers. comm., 23 May 1989).

Crossley (1956) reports that white spruce transplants lifted and hot-planted throughout the growing season in Alberta demonstrated satisfactory survival for the entire planting period of each of the 3 years in his study, with the exception of planting dates which coincided with very dry soils. Ackerman and Johnson (1962) discuss data from the same study, collected 5 years after each planting, which demonstrate continued good, overall survival, but also a decline in height increment with increasing delay after the first planting date. The authors also caution that the data should be qualified because the transplant beds of the nursery and the area transplanted were located nearby, so the seedlings were exposed to little stress during the planting procedures. Ferdinand *et al.* (1974) also note that while container seedlings may be planted from May to August, summer drought makes many parts of Alberta suitable for planting only in early spring and late fall.

Burgar and Lyon (1968) report that hot-lifted 2+2 white spruce showed satisfactory survival in northern Ontario during the entire planting period (at 2-week intervals from early June until late October), although some reduction in survival occurred with stock planted when shoots were actively elongating. For September and October plantings, height growth of the plants was also greatly reduced, even after 3 years. Of note is the fact that the summer of the study had 660 mm of well-distributed rain between May and October, 230 mm greater than normal.

Finally, Arnott (1974) reports trials of container and bareroot lodgepole pine and white spruce seedlings planted throughout the June - September period in interior British Columbia. The survival of the white spruce declined with later planting dates, but date of planting did not affect lodgepole pine survival significantly.

Stock Type

The early papers concerned with the effects of season on plantation establishment and growth were confined to comparisons of bareroot seedlings with transplants. Given the relatively snow-free periods of nurseries and most planting areas in sub-boreal and boreal forests discussed earlier, the use of such stock is strongly constrained by seedling phenology and physiology.

The increased development and use of container seedlings during the past 20 years have allowed trials to use stock types that are much more flexible than bareroot seedlings. Because container seedlings may be grown in greenhouses where the environment can be closely controlled, seedlings whose phenology and physiology are optimum for any planting schedule can be produced (Lavender and Cleary, 1974). And, because movement of container seedlings is not limited by the condition of bareroot seedbeds, such plants afford favourable options not available with traditional nursery stock. For example, container seedlings may be maintained out-of-doors in nurseries with mild fall climates until their physiological condition will permit maximum tolerance of cold storage conditions. A second alternative for container seedlings, again in nurseries with mild winter climates, is to overwinter the stock out-of-doors, stimulate a second-year shoot elongation during April and May, and produce dormant seedlings suitable for planting from July to September.

A third scenario involves sowing seed in January, maintaining seedlings under favourable conditions in a greenhouse during late winter and spring, and inducing dormancy so that plants have well-formed buds by late June (Arnott 1974). The hot-planting following these last two scenarios has produced good survival and growth for white spruce seedlings in British Columbia (LePage and Pollack 1986). It should

be recognized, however, that while such seedlings are apparently "dormant" (i.e., possess well-formed buds), they have little cold resistance and are, therefore, subject to damage wherever summer frosts are prevalent.

Storage

Thus far we have discussed the growth and survival of fresh-lifted, hot-planted seedlings, though we have also noted that one option available for the silviculturist is to use seedlings that have been cold-stored for varying periods at temperatures ranging from +2 to -2°C. Foresters generally consider cold storage to be a benign method for maintaining seedling vitality until designated plantation areas are free of snow. To a certain extent, if the storage procedure is carefully implemented, this is true (Racey *et al.* 1984). However, even the best of the current cold storage facilities are very artificial in that there is no variation in the seedlings' environment during the storage period.

Coniferous seedlings, in common with most living organisms, have evolved in an environment characterized by strong daily rhythms (Circadean) as shown by the day-night sequence. When seedlings are deprived of such a fluctuating environment, their vigour can be significantly reduced (Hermann 1967; Lavender and Wareing 1972). One result of such reduced vigour is that spruce seedlings are much less able to grow roots at low soil temperatures. A second negative effect of cold storage is that seedlings are unable to conduct photosynthesis, but continue to respire, albeit at significantly reduced rates. Such respiration definitely depletes seedling carbohydrate reserves (Ritchie and Dunlap 1980; Ritchie 1982). The net result of cold storage is that seedlings do not have the opportunity for positive photosynthesis, which occurs in nature during periods of above-freezing temperatures in winter, and much of the carbohydrate synthesized in summer and fall is lost, leaving the plant with depleted food reserves to support shoot elongation.

In spite of the foregoing negative potential of cold storage, this procedure is widely practised in Canadian silviculture because it allows seedlings to be kept at a relatively appropriate morphological state until outplanting areas are accessible in spring. It also obviates the possible damaging effects of winter weather which may result in desiccated or frozen seedlings, and frequently results in less damage in spring than may occur with spring-lifted stock (Sutton 1982).

Sutton (1984) reviews a number of reports which indicate that fall-lifted, cold-stored stock may have comparable survival and subsequent growth to stock spring-lifted and planted. However, he cautions that such positive results depend strongly on initiating storage only after the stock is physiologically able to resist the stress involved, and on maintaining optimum conditions during the storage period to prevent the development of molds or root damage from sub-freezing.

A second regime for the use of cold-stored stock involves lifting seedlings in spring and cold-storing them for use in summer planting programs. This scenario has good potential for establishing vigorous plantations, although Sutton (1982) reviews a number of papers which emphasize that seedlings must be lifted at the earliest possible date if such potential is to be realized. Trials of early spring-lifted seedlings have shown that such stock is not subject to a period of low stress resistance because there is no shoot elongation in late spring or early summer before outplanting. However, the high survival reported for late spring and early summer planting of cold-stored stock does not continue for seedlings planted in late summer (Simon 1961; Burgar and Lyon 1968; Low 1973; Sinclair and Boyd 1973; McClain 1982; Sutton 1982; LePage and Pollack 1986). Sutton (1982) also reports reduced height growth after 4 years for white spruce with each 2-week delay in planting after the end of June. Clearly, the current consensus is that cold-stored stock for summer planting should only be used until late June.

Sutton (1984) further emphasizes that such seedlings should be lifted before bud swell in spring, protected from desiccation and physical damage, and stored under conditions that will inhibit mold development. The maximum storage time for stock stored above freezing is 8 weeks, whereas frozen stock may be outplanted until early July. These conclusions are confirmed by Mullin's study of spring-lifted, then frozen white spruce and red pine (Mullin 1978) which showed that early lifting was essential to good survival and growth of stored stock, and that with increasing delay of lifting date, the early lifted and

stored stock was progressively superior to hot-lifted seedlings. Other trials (Mullin and Forcier 1976; Mullin and Reffle 1980) have yielded similar data for white and black spruce and jack pine.

The sharp decline in seedling survival and growth with delay in planting of stored white spruce seedlings in the summer is attributed by Sutton (1984) to increasing disparity between the growth stage of the stock and the sequence of weather patterns. He reports that spruce planted after late July were unable to complete their flush of shoot growth and develop frost resistance before the initiation of cold weather in the fall. Consequently, such seedlings suffered great damage from the early fall frosts. Burgar and Lyon (1968) and Revel and Coates (1976) report data which clearly demonstrate this response for late summer plantings of white spruce.

Site Preparation

A series of trials of white spruce seedlings hot-planted during the summer in British Columbia (Revel and Coates,1976; Revel 1985, 1989) showed that such plantings are best used on areas that have been burned, and should not be attempted after mechanical site preparation, which exposes bare mineral soil and risks frost heaving of container seedlings. The risk is particularly great for plantings after 31 July and on sub-hygric sites.

The major way that the soil environment may affect the success of plantations established at different seasons of the year is by limiting seedling root growth before adverse weather events. As noted previously, for example, fall planting on fine-textured soils can result in frost heaving if the plantations are subject to frosts that occur before elongation of seedling roots. Similarly, late spring planting in areas subject to summer drought often results in high mortality of seedlings before they are able to re-establish the root-soil contact necessary to absorb effectively the limited moisture supplied (Sutton 1982).

Vegetative Competition

A large body of literature documents the strong adverse effects that competing vegetation may have on plantation establishment (Cleary *et al.* 1978), but there is no evidence that such competitive effects are a function of the season of planting.

SUMMER PLANTING OF CONIFEROUS SEEDLINGS IN BRITISH COLUMBIA

We have summarized the results of research with spruce and pine in North America, which are germane to understanding how planting date affects plantation survival and growth. The remainder of this report discusses information derived from trials of hot-planted and cold-stored seedlings planted during the summer months in British Columbia.

Bareroot White Spruce

As early as weather permitted in the springs of 1968-1970, 2+0 and 2+1 white spruce seedlings and transplants were lifted from the seedbeds at the Red Rock nursery and stored in multi-wall bags at 1.5° C. Some of the 2-0 seedlings were soon transplanted in the nursery at 5-cm spacing (Revel and Coates 1976).

Beginning on 13 June of each year and continuing at 2-week intervals until 3 October, 90 cold-stored and freshly lifted 2+1 transplants and 90 cold-stored 2+0 seedlings were planted near the southwest corner of McLeod Lake. The experimental site had been harvested in 1964 and burned in 1967. The site was predominantly Devil's Club association (mesic to sub-hygric sites in the wet, cool Sub-Boreal Spruce Zone) on a gravelly, fine-textured till soil. Drainage was generally good. The annual planting design included three completely randomized blocks, each block containing a 30-seedling replicate of each stock type for each planting date.

Survival and growth of all planted material were recorded each year for 3 years after planting. Regression analyses of these data resulted in the following equations:

1. Survival of fresh-lifted 2+1 transplants after 3 years:
   Survival = 57.31 + 0.11 (Julian date); $R^2 = 0.11$
2. Survival of cold-stored 2+1 transplants after 3 years:
   Survival = 129.65 - 0.31 (Julian date); $R^2 = 0.24$
3. Survival of cold-stored 2+0 seedlings after 3 years:
   Survival = 107.80 - 0.20 (Julian date); $R^2 = 0.13$
4. Total height of fresh-lifted 2+1 transplants after 3 years:
   Total height (cm) = 39.6 - 0.03 (Julian date); $R^2 = 0.02$
5. Current leader growth of fresh lifted 2+1 transplants after 3 years:
   Current leader growth (cm) = 22.5 - 0.06 (Julian date); $R^2 = 0.14$

These show that the planting date had little effect on the survival or height growth of freshly lifted 2+1 stock. However, transplants planted before 1 July generally had slightly greater total height and third-year height increments than did similar stock planted after 1 August. The high survival clearly reflects the care exercised during the entire trial, even though the one planter employed did plant at a rate of 90 transplants per hour to simulate operational reforestation. Most of the height growth the year of planting occurred in the nursery before the first planting date, June 13. The reduced height growth of the August - October plantings in following years probably reflects: 1) the effects of lifting and planting on roots, which doubtless received some damage during a period of low growth potential; and 2) the generally reduced stress resistance common to temperate zone plants in late summer and early fall.

In contrast with the above, the survival of cold-stored trees was definitely affected by date of planting, with late planted seedlings and transplants having much lower survival than those planted before 1 August. Although we have no definitive data to explain this poor survival, the following hypotheses are supported by studies of seedling physiology (Lavender 1990). First, the major cause of mortality seems to be a disruption of normal annual growth rhythms. Seedlings planted in late summer and early fall initiated shoot elongation at the time when they would normally be in dormancy. Accordingly, they were ill-prepared to withstand low temperatures or respond to the chilling necessary before growth the following spring.

Second, a probable lesser cause of mortality was the depletion of carbohydrate reserves during storage. Finally, while the first few planting dates were typical of conventional spring and early summer planting, later plantings were in varying stages of active growth late in the growing season and therefore susceptible to late summer frosts. The adverse effects of late planting were also evident in reduced shoot growth for the 3-year study period after planting. The average total height of both 2+1 and 2+0 stored stock after 3 years was 27 cm for plantings before 1 August and 13 cm for the latter planted material. Similarly, the current year's shoot elongation 3 years after planting was 9 cm for seedlings and transplants planted before 1 August and 4 cm for the latter plantings.

If standards of 80% survival and a minimum of 25 cm height growth in 3 years are realistic minima, then all the planting dates resulted in satisfactory performance of freshly lifted stock. However, problems were encountered with the first planting date of freshly lifted transplants. On this date, 13 June, the transplants were at the height of the spring flush, new growth was succulent, and the stock was very susceptible to moisture stress. By 1 July, these conditions no longer existed as transplants had set at least bud initials and were more resistant to stress.

Survival of cold-stored seedlings was adequate when they were planted up until the middle of July, but it rapidly diminished after that. The effects of the later plantings were characterized by widespread mortality of the main stem as a result of frost injury, followed by limited lateral growth from adventitious buds over the next few years. Field observations over 5 years show that August plantings are the most susceptible to frost damage, and that frost injury can occur in succeeding years, resulting in small seedlings with multiple tops.

All June plantings resulted in excellent performance. However, the use of cold stored stock is recommended for that month, because freshly lifted stock is extremely tender then and requires careful handling. Freshly lifted stock planted in July out-performed cold-stored stock; but cold-stored stock could be used until mid-July.

The results of this work therefore show that the conventional planting period can be extended to include the entire snow-free period in the Sub-Boreal Forest Region of British Columbia if a combination of cold-stored and freshly lifted planting stock is used. Close liaison with the nursery is very important, however, so that no more than 3 days' supply of stock is held at the planting site.

Container-Grown Seedlings

With the increasing use of container-grown white spruce in a summer planting program, a controlled survey of operational planting was conducted between 1984 and 1986. Each year, five representative operational summer planting projects were selected for monitoring. These plantations represented a variety of biogeoclimatic zones and sub-zones in mesic to sub-hygric site associations in the Sub-Boreal Spruce Zone, as well as a variety of stock types and nurseries. No attempt was made to study nursery or stock effects. Rather, the populations were considered to be representative of the annual mid-July to mid-August planting program.

Data were collected from randomly located staked plots: four such plots of 25 seedlings each, for each plantation examined. Survival, total height, and leader length of each seedling were recorded during the year of planting, and for two subsequent growing seasons. These data are summarized in Tables 1-3.

Survival for all plantations after three growing seasons averaged 78%. Unacceptable survival occurred at Catfish Creek in 1984, which was not related to the time of planting. At the site, deep duff was suspended over a water table and the seedlings underwent losses to root collar weevils.

Generally acceptable to good root egress, as determined by periodic examination of root systems, occurred in most of the plantations studied. In July and early August on mesic to sub-hygric sites, soil temperatures in the rooting zone were between 8 and 12°C, which promoted active root egress. In late August, however, particularly on sub-hygric sites, temperatures were in the 5–7°C range. This may be marginal for root growth, curtailing root egress.

TABLE 1. Survival and growth of white spruce seedlings planted in the summer of 1984

Location and sub-zone	Stock type	Height at planting (cm)	Fall 1985			Fall 1986		
			Height (cm)	Leader (cm)	Survival (%)	Height (cm)	Leader (cm)	Survival (%)
Missinchinka SBSwk (McLeod *et al.* 1987)	PSB 211+1	25.5	30.9	5.4	99	33.4	1.4	94
Tumbler Ridge BWBS (Delong *et al.* 1990)	2+1	21.9	24.0	2.1	86	25.2	1.7	78
Wonowon BWBS	PSB 211+2	28.1	29.6	3.1	88	29.6	1.5	68
Pinchi Lake SBSdw (McLeod *et al.* 1987)	PSB 211(2+0)	22.2	28.8	6.6	74	34.4	4.4	70
Catfish Cr. ICH	PSB 211	24.4	28.4	4.0	57	29.7	2.7	49.1[a]
Average		24.4	28.3	4.2	81	30.5	2.3	72

[a] At this site, deep duff was suspended above an open water table and root collar weevils infested the seedlings.

TABLE 2. Survival and growth of white spruce seedlings planted during the summer of 1985

Location and sub-zone	Stock type	Height at planting (cm)	Fall 1986			Fall 1987		
			Height (cm)	Leader (cm)	Survival (%)	Height (cm)	Leader (cm)	Survival (%)
Osborn BWBS	PSB 313(2+0)	19.1	25.8	7.1	96	29.5	4.5	92
Stephen Lake SBSwk1	PSB 313(2+0)	24.8	31.0	6.7	71	38.2	7.4	70
Gagnon Cr. SBSwk	PSB 313 (1+0)	17.1	24.1	9.0	93	31.0	8.9	92
McKale Rd. ICHmm	PSB 313 (2+0)	30.5	31.0	5.3	73	33.6	2.8[a]	73
Bill's Cr. SBSwk	1.5+1.5	22.2	27.4	9.8	95	28.7	2.0	85
Average		22.7	27.9	7.6	86	32.2	5.1	82

a Leaders damaged by frost.

TABLE 3. Survival and growth of white spruce seedlings planted during the summer of 1986

Location and sub-zone	Stock type	Height at planting (cm)	Fall 1987			Fall 1988		
			Height (cm)	Leader (cm)	Survival (%)	Height (cm)	Leader (cm)	Survival (%)
Buick Cr. BSBW	PSB 313	19.7	29.3	10.1	97	35.7	2.1[a]	84
Ptarmigan Cr. ICHwk3	1.5+1.5	20.1	26.8	7.0	87	32.1	8.5	90
Little Field Cr. SBSwk	PSB 313 (2+0)	26.5	33.1	8.4	92	40.2	9.4	90
Tannizul (TFL42) SBSwk	1.5+1.5	24.6	24.8	4.3	70	23.3	4.6[b]	65
Summit Lake SBSwk	PSB 313 (2+0)	18.1	22.1	6.8	75	33.7	11.4	71
Average		21.8	27.2	7.3	84	33.0	7.2	80

a Severe frost heaving on mechanically prepared mounds; and seedlings were not able to establish on the heavy clay loam.
b Leaders damaged by frost.

Root egress is required to establish a "water chain" and to anchor seedlings, so reducing frost heaving. Satisfactory root egress is a fundamental factor in successful summer planting, which is recommended before mid-August before low soil temperatures occur in the Boreal and Sub-Boreal Zones. This is very important in sub-hygric sites and sites that have been mechanically prepared to expose mineral soil. On sites prepared by broadcast burning where more than 2 cm of insulating duff are present, frost heaving is not generally a significant problem.

Experience has shown the high success of planting on well-executed prescribed burns. The results of summer planting also substantiate this. Results are not as predictable or consistent after mechanical site preparation. Frost heaving, "baking," and flooding are more common following such treatment than under prescribed burn conditions. Since a major proportion of backlog site preparation must be mechanically prepared, special precautions are necessary. To reduce frost heaving, summer planting on mechanically prepared backlog sites should be restricted to warmer soils, and to moderately well- to well-drained

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(mesic) associations. Planting in clay loams and silt loams should be done in the spring to allow a longer period for root establishment (or, if summer planted, not after 31 July).

In general, summer planting should be directed to sites that have had good prescribed burns, and spring planting to sites that have had good prescribed burns or mechanical treatment.

In addition to the operational surveys discussed above, controlled studies of the effects of cold storage on seedling vigour for a range of summer lifting and planting dates were conducted at nurseries on the UBC campus and at Red Rock between 1986 and 1988. Seedlings used in these trials were container-grown PSB 313 white spruce, randomly selected from operational lots of seedlings. The stock was lifted after bud set in late June, July and early August. The experimental design consisted of two completely randomized blocks, each containing one 10-seedling row for each planting date and storage period. Seedling survival was recorded in the fall of 1986 and the date of bud break and 1987 shoot elongation recorded the following year.

None of the treatments affected seedling survival, which was 100% for the test populations. Nor was the date of bud break in 1987 affected by either planting date or storage time. A statistical analysis of the data in Table 4 shows that the seedlings lifted in August had a significantly reduced shoot elongation (compared with the remaining populations) the following year. Likewise, the data in Table 5 show a general reduction in diameter growth in 1987 with a delay in the 1986 planting date. However, both tables suggest that seedlings may be stored for as long as 12 days without a significant reduction of seedling vigour.

TABLE 4. The effect of date of lifting and storage period in 1986 on the shoot elongation of white spruce seedlings in 1987

Length of storage (days)	Shoot elongation (cm) 1987, by lifting date				
	June 30	July 14	July 28	Aug. 11	Mean
2	10.6	9.9	9.8	6.4	9.2
12	9.4	11.2	9.5	6.8	9.2
22	7.5	10.8	8.3	5.6	8.0
Mean	9.2	10.6	9.2	6.3	8.8

TABLE 5. Effect of planting date and storage time on diameter growth

Storage period (days)	Seedling diameter (mm) by planting date				
	June 30	July 14	July 28	Aug. 11	Mean
2	8.59	8.41	6.81	6.57	7.60
12	7.66	7.48	7.10	6.99	7.31
22	7.41	7.61	7.28	6.68	7.24
Mean	7.89	7.83	7.06	6.75	7.38

Data recorded for the outplantings at the Red Rock nursery were confined to seedling survival and bud break in 1987. Neither planting date nor storage period affected either parameter.

A second trial was initiated at the UBC nursery in 1987 with white spruce seedlings lifted at 2 week intervals from 30 June until 8 September and stored for 2, 9, or 16 days. The study consisted of the same experimental design as that employed the previous year. Again, seedling survival exceeded 99%. Only one plant died in the entire population. Data from this trial were recorded in the fall of 1988 and are summarized in Tables 6-10.

TABLE 6. Effect of date of lifting and storage period in 1987 on white spruce seedling diameter in 1988

	Seedling diameter (mm), October 1988 by storage period (days)			
Lifting date	2	9	16	Mean
30 Jun 1987	6.63	5.57	6.67	6.29
14 July 1987	6.35	6.90	6.12	6.46
28 July 1987	6.51	6.51	6.56	6.53
11 Aug 1987	6.26	6.01	5.69	5.99
25 Aug 1987	5.85	4.97	5.42	5.41
8 Sep 1987	5.29	5.34	5.13	5.25
Mean	6.15	5.88	5.93	5.99

TABLE 7. Effect of date of lifting and storage period in 1987 on white spruce seedling total height in 1988

	Seedling total height (cm), October 1988 by storage period (days)			
Lifting date	2	9	16	Mean
30 Jun 1987	30.5	25.1	30.7	28.8
14 July 1987	34.6	32.2	30.7	32.5
28 July 1987	31.4	31.7	32.5	31.9
11 Aug 1987	32.1	30.7	30.4	31.1
25 Aug 1987	30.0	26.5	27.7	28.1
8 Sep 1987	30.3	28.5	27.1	28.6
Mean	31.5	29.1	29.8	30.1

TABLE 8. Effect of date of lifting and storage period in 1987 on dry weight of white spruce seedling shoots in October 1988

	Dry weight of seedling shoot (g) by storage period (days)			
Lifting date	2	9	16	Mean
30 Jun 1987	11.77	9.03	12.12	10.97
14 July 1987	11.62	11.92	10.81	11.45
28 July 1987	10.69	10.57	10.07	10.44
11 Aug 1987	9.48	9.21	9.25	9.31
25 Aug 1987	8.08	6.36	6.86	7.10
8 Sep 1987	7.28	7.29	5.96	6.83
Mean	9.81	9.06	9.18	9.35

TABLE 9. Effect of date of lifting and storage period in 1987 on dry weight of white spruce seedling roots in October 1988

Lifting date	Seedling total height (cm), October 1988 by storage period (days)			
	2	9	16	Mean
30 Jun 1987	5.38	4.46	5.26	5.03 ab
14 July 1987	5.41	5.57	5.13	5.37 a
28 July 1987	6.31	5.15	4.93	5.46 a
11 Aug 1987	5.65	4.67	5.02	5.11 a
25 Aug 1987	5.19	4.28	3.86	4.44 bc
8 Sep 1987	4.34	3.94	4.37	4.23 c
Mean	5.38 d	4.68 e	4.76 e	4.94

Mean data with the same letter are not different at 95% probability.

TABLE 10. Effect of date of lifting and storage period in 1987 on total dry weight of white spruce seedlings in October 1988

Lifting date	Total dry weight of seedling (g) by storage period (days)			
	2	9	16	Mean
30 Jun 1987	17.15	13.49	17.38	16.01
14 July 1987	17.03	17.49	15.94	16.82
28 July 1987	17.00	15.72	15.00	15.91
11 Aug 1987	15.13	13.88	14.27	14.43
25 Aug 1987	13.27	10.64	10.72	11.52
8 Sep 1987	11.57	11.20	10.33	11.03
Mean	15.19	13.74	13.94	14.29

For seedling diameter, height, and dry weight of shoots, we cannot say how significant either treatment is because of the considerable interaction between effects of date of lifting and length of storage. There is, however, evidence of two general trends: reduced seedling growth after storage periods greater than 2 days, and after planting dates later than August 11. The data in Tables 9 (dry weight of seedling roots) and 10 (seedling total dry weight) confirm these trends.

Other recent (1987) trials of summer planting in British Columbia include plantations established near Kamloops (A. Vyse, pers. comm., 23 May 1989). These white spruce plantings were made at 2-week intervals from 2 July until 24 September at three biogeoclimatic subzones: 1) ESSFwc (1550 m); 2) MSxk (1400 m); and 3) ESSFdc (1600 m). The lowest site was blade-scarified before planting; the other two areas were not site-prepared. Survival in the fall of 1988 was 97, 92, and 70%, respectively. The lower survival at the highest elevation reflected frost damage of seedlings planted before 30 July and after 10 September. The survival data suggest that storage of seedlings as long as 16 days (longest period tested) did not affect survival. Nor did planting date or storage period affect seedling diameter or height growth on the lower sites.

Finally, summer trials in the southern Interior were conducted in 1987 by Weyerhaeuser Canada Ltd. (R. Willis, pers. comm., 29 May 1989). These trials included both lodgepole pine and white spruce seedlings on two contrasting sites. The first, near Lumby, with rocky soils and a southerly aspect at 1750 m was machine site-prepared. The second, near Vavanby, with good soils and an east aspect at 1380 m, was burned. Seedlings were planted on the following dates: 1 July, 21 July, 11 August, and 1 September.

Survival of lodgepole pine in the summer of 1988 was over 90% for all plantings on both areas. Survival of white spruce was over 90% for all dates in the Vavanby plantation and the August and September plantings near Lumby, but 68% and 80% for the earlier plantings on this site.

These trials suggest that late summer plantings may be preferable to earlier dates, particularly for spruce, but the results otherwise confirm the findings reported earlier in this paper for the Prince George area.

CONCLUSIONS

Experience in British Columbia with summer planting of white spruce seedlings suggests the following general guidelines for the use of this practice.

Summer planting has yielded the best results when the planting has followed well executed prescribed burns. The results are not as predictable or consistent after mechanical site preparation. Frost heaving, "baking," and flooding are more common with this type of site preparation than with burning. Summer planting on mechanically prepared sites should be restricted to associations which are moderately to well-drained (mesic), to reduce frost heaving and to provide warmer soils. Clay loams and silt loams should not be planted after July 31. Finally, summer planting after mechanical site preparation that has exposed bare mineral soil should be avoided, as such micro-sites are particularly prone to frost heaving of container grown seedlings. The risk is especially high for plantings after the end of July and on sub-hygric sites.

The nursery data do not demonstrate a strong effect of either planting date or storage period. However, as noted, there are definite trends of reduced seedling vigour with increasing length of storage and delay of planting date. Furthermore, these trends are evident with seedlings that have been handled very carefully and, since there is evidence that seedling resistance to stress is reduced after any adverse events, such trends will likely be more pronounced under operational conditions. Planting is therefore recommended before August, and any storage of seedlings should be kept to a minimum.

In an unpublished summary of experience with summer planting in the Prince George Forest Region, [1] additional recommendations are also made:

- A cautious and carefully monitored program of summer planting of lodgepole pine should be initiated.
- Root regeneration capacity (RGC) should be periodically measured for all seedlots at the time of shipment from the nursery, and correlated with root egress in the forest soil. More information about the relationship between root growth and soil temperature is needed.
- Soil temperatures in the rooting zone should be measured on a routine basis and correlated with root egress on a representative sample of summer planting projects. Minimum temperatures which will permit rapid root egress of summer-planted seedlings should be determined.
- Seedlots should be designated for summer planting at time of sowing request, and should, where possible, be grown locally. These seedlots should be subjected to special cultural regimes (e.g., reduced irrigation or appropriate photoperiods) to condition them for summer planting, but not severely stressed.

Finally, because "dormant" seedlings (i.e., seedlings with a terminal bud) have little frost hardiness in mid-summer, the use of summer planting is not recommended in areas subject to severe (less than -4°C) summer frosts.

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[1] Revel, J. 1985. Planting white spruce seedlings throughout the growing season in the Prince George Forest Region. Ministry of Forests, Prince George. Unpublished report.

BIBLIOGRAPHY

Ackerman, R.F. and H.J. Johnson. 1962. Continuous planting of white spruce throughout the frost-free period. Can. Dep. For., For. Res. Br., Ottawa, Ont. Tech. Note No. 117. 13 p.

Arnott, J.T. 1974. Performance in British Columbia. *In* Proc. N. Am. Containerized Forest Tree Seedling Symp., Denver, Colo. R.W. Tinus, W.I. Stein, and W.E. Balmer (editors). Great Plains Agric. Council Publ. No. 68, pp. 283-290.

Burgar, R.J. and N.F. Lyon. 1968. Survival and growth of stored and unstored white spruce planted through the frost-free period. Ont. Dep. Lands For., Res. Br., Toronto, Ont. Report No. 84.

Cleary, B.C., R.D. Greaves, and R.K. Hermann. 1978. Regenerating Oregon's forests. Oreg. State Univ., Exten. Serv., Corvallis, Oreg.. 287 p.

Crossley, D.I. 1956. The possibility of continuous planting of white spruce throughout the frost-free period. Can. Dep. North. Affairs and National Resources, Res. Br., For. Res. Div., Ottawa, Ont. Tech. Note No. 32. 27 p.

Delong, C., A. MacKinnon, and L. Jang. 1990. Ministry of Forests field guide for identification and interpretation of ecosystems of the northeast portion of the Prince George Region. B.C. Min. For., Victoria, B.C. Land Manage. Handb. 22.

Ferdinand, S.I., W.C. Kay, and A.K. Hellum. 1974. Container program in Alberta. *In* Proc. N. Am. Containerized Forest Tree Seedling Symp., Denver, Colo. R.W. Tinus, W.I. Stein, and W.E. Balmer (editors). Great Plains Agric. Council Publ. No. 68, pp. 44-52.

Hermann, R.K. 1967. Seasonal variation in sensitivity of Douglas-fir seedlings to exposure of roots. For. Sc. 13(2):140-149.

Lavender, D.P. 1990. Physiological principles of regeneration. *In* Regenerating British Columbia's forests. D.P. Lavender, R. Parish, C.M. Johnson, G. Montgomery, A. Vyse, R.W. Willis, and D. Winston (editors). Univ. B.C. Press, Vancouver, B.C., pp. 30-44

Lavender, D.P. and B.D. Cleary. 1974. Coniferous seedling production techniques to improve seedling establishment. *In* Proc. N. Am. Containerized Forest Tree Seedling Symp., Denver, Colo. R.W. Tinus, W.I. Stein, and W.E. Balmer (editors). Great Plains Agric. Council Publ. No. 68, pp. 177-180.

Lavender, D.P. and P.F. Wareing. 1972. Effects of day length and chilling on the responses of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). seedlings to root damage and storage. New Phytologist 71:1055-1067.

LeBarron, R.K., G. Fox, and R.H. Blythe, Jr. 1938. The effect of season of planting and other factors on early survival of forest plantations. J. For. 36:1211-1215.

LePage, P. and J.C. Pollack. 1986. An all-season container and bareroot planting trial of lodgepole pine and white spruce: 14-year results. B.C. Min. For., Victoria, B.C. FRDA Report No. 004. 28 p.

Limstrom, G.A. 1963. Forest planting practice in the Central States. U.S. Dep. Agric. For. Serv. Agric. Handb. No. 247. 69 p.

Low, A. J. 1973. The effective planting season in Scotland. Scottish Forestry 27:4-8.

McClain, K.M. 1982. The question of extending the planting season. Proc. Ont. Nurseryman's Meet., Thunder Bay, Ont. Ont. Min. Natural Resources. 13 p.

McLeod, A., G. Hope, C. Delong, and A. MacKinnon. 1987. B.C. Ministry of Forests field guide for identification and interpretation of ecosystems of SDSk3 and j2 in Prince George Forest Region. B.C. Min. For., Victoria, B.C.

Mullin, R.E. 1978. Tests of frozen spring storage for white spruce and red pine planting stock. Tree Planters' Notes 29 (4):26-29.

Mullin, R.E. and L.J. Forcier. 1979. Spring lifting and storage of jack pine at Swastika Nursery. Ont. Min. Natural Resources. Nursery Note No. 59. 7 p.

Mullin, R.E. and J.D. Parker 1974. Bales versus polybags in cold and frozen overwinter storage of nursery stock. Can. J. For. Res. 4:254-258.

_____. 1976. Provisional guidelines for fall lifting for frozen overwinter storage of nursery stock. The Forestry Chron. 52(1):1-4.

Mullin, R.E. and R.J. Reffle. 1980. Effects of dates of lifting and planting on success of frozen spring storage at Swastika Nursery. Ont. Min. Natural Resources. Nursery Note. No. 66. 5 p.

Racey, G.D., R.E. Hutchison, and C. Glerum. 1984. Effect of extended cold storage after overwinter frozen storage of white pine and white spruce. Ont. Min. Natural Resources. For. Res. Br. Nursery Note No. 105. 5 p.

Revel, J. 1985. Planting white spruce throughout the growing season in the Prince George Forest Region. *In* Interior Spruce Seedling Performance Symp. North. Silv. Committee, Prince George, B.C.

_____. 1989. Analysis of summer planting for backlog sites: progress report. *In* Learning from the past; looking to the future. B.A. Scrivener and J.A. MacKinnon (editors). B.C. Min. For., Victoria, B.C. FRDA Report No. 030. 140 p.

Ritchie, G.A. 1982. Carbohydrate reserves and root growth potential in Douglas-fir seedlings before and after cold storage. Can. J. For. Res. 12:905-912.

_____. 1985. Root growth potential: principles, procedures, and predictive ability. *In* Evaluating seedling quality: principles, procedures, and predictive abilities of major tests. M.L. Duryea (editor). Oreg. State Univ., For. Res. Lab., Corvallis, Oreg., pp. 93-105.

Ritchie, G.A. and J.R. Dunlap. 1980. Root growth potential: its development and expression in forest tree seedlings. N.Z. J. For. Sc. 10:218-248.

Silim, S.N., T. Kannangara, D.P. Lavender, and L. Charleson. 1989. Effects of photoperiod and plant growth regulators upon the growth of coniferous seedlings. Forestry 62, Suppl. 143-148.

Simon, C.L. 1961. Effects of lifting date, cold storage and grading on survival of some coniferous nursery stock. J. For. 59:449-450.

Sinclair, C. and R.J. Boyd. 1973. Survival comparisons of three fall and spring plantings of four coniferous species in Northern Idaho. U.S. Dep. Agric. For. Serv. Ogden, Utah. Res. Paper INT-139. 20 p.

Stiell, W.M. 1976. White spruce: artificial regeneration in Canada. Dep. Environ., Can. For. Serv., Ottawa, Ont. Inf. Rep. FMR-X-85. 275 p.

Stone, E.C., J.L. Jenkinson, and S.L. Krugman. 1962. Root regenerating potential of Douglas-fir seedlings lifted at different times of the year. For. Sc. 8:288-297.

Sutton, R.F. 1982. Plantation establishment in the Boreal forest: planting season extension. Dep. Environ., Can. For. Serv. Great Lakes For. Res. Cent., Sault Ste. Marie, Ont. Report 0-X-344. 129 p.

_____. 1984. Bare-root planting season options. The Forestry Chron. 60(6):328-334.